

Spirulina Platensis: A Natural Product with many Biological Properties

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Abstract: The human population are continuously increasing; the concern about food, global warming, outbreak of diseases, and other environmental issues are also increased but thanks to nature which provides a viable solution and a good resource which are cyanobacteria (blue-green algae). *Spirulina platensis* is spiral coil blue-green algae, free-floating filamentous undifferentiated cyanobacterium that live both in the sea and freshwater and belong to the family of Oscillatoriaceae. They are non-heterocyst found in warm bodies of water in tropical and subtropical regions with high elevated pH, salinity, carbonate & bicarbonate content. *Spirulina* has different pigments such as carotenes, phycobilins, chlorophylls, phycocyanin and phycoerythrin. It contains high protein, chemicals, vitamins and various bioactive compounds used as food supplements, therapeutics, and diagnostics. *Spirulina* has antioxidant, antimicrobial, antibacterial, anti-inflammatory, and antiparasitic properties which play an important role in human life. *Spirulina* is used as a model organism in a variety of studies in medical sciences, environmental science, and biotechnology. The aim of this review is to summarize the importance of cyanobacterial species on human health.

Keywords: Cyanobacteria, Natural Product, *Spirulina platensis*, Therapeutics.

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I. INTRODUCTION

Spirulina is a free-floating planktonic belonging to the oxygenic photosynthetic cyanobacteria and is largely distributed in nature. It has been producing oxygen in Earth's atmosphere for 3 billion years [1]. *Spirulina* is found naturally in warm water bodies, alkaline lakes, volcanic lakes, seawater, and freshwater but under favourable conditions, it is synthetically produced in the ponds of the greenhouse and outdoors. These algal biomasses are a rich source of biologically active compounds and metabolites. It contains various food supplements such as essential amino acids, protein, vitamins (vitamin B12 and provitamin A), minerals, and fatty acid such as γ – linolenic acid, and sulfolipid [2]. *S. platensis* produces primary and secondary metabolites which are bioactive compounds used in the drug industry [3-5]. It also has anticancer, anti-inflammatory, antioxidant, antibacterial, antifungal, and antiparasite properties [6]. *S. platensis* pigment chromophore phycocyanin has hepatoprotective and neuroprotective characteristics [7-12]. *Spirulina* works as

an immunomodulator it enhances the immune system that can stimulate the production of antibodies. It initiates B-cells, T-cells, natural killer cells and macrophages to produce interferon γ and stimulate expression of different types of cytokines. It acts as an inhibitor against enveloped viruses including influenza A, Herpes Simplex Virus Type I (HSV-1), Human Immunodeficiency Virus-1 (HIV-1), Human Cytomegalovirus, and Measles virus, by blocking replication of viruses after probing in the cell and it also stops the virus to enter in the cell [13]. It has various unique characteristics which encourage scientists for its industrial advantage. Cyanobacterial bioactive molecules hold a bright and promising future in scientific research and a great opportunity for drug discovery and prevalence in the future for clinical application.

II. PROPERTIES OF SPIRULINA

➤ Nutritional Properties

Spirulina is blue-green algae which is an ideal food and is used as nutraceutical dietary supplements in the 21st century [14]. It is known as the future food with various constituents and high energy. Some constituents are polysaccharides like glycogen and essential fats like Gamma linolenic acid (GLA) which are readily consumed by human cells and release energy. Studies found that spirulina in intestine extend lactobacillus which produces vitamin B6 [15]. Spirulina contains approximately 70% protein content and has 18 amino acids [16]. It is a potential source of vitamins such as provitamin A and vitamin B₁₂ [17, 18]. In spirulina, lipid comprises 4-7%, Carbohydrates 13.6%, Water 5%, RNA (Ribonucleic Acid) 2.2%-3.5% and DNA (Deoxyribonucleic Acid) is about 0.6 %-1% [19-20]. Spirulina has calcium content approx. 700-1000 mg /100g which is higher than vegetables and dairy products so it also involves in bone probity. Spirulina is also used as a diet as it provides sufficient iron which reduces the prevalence of anaemia during pregnancy and lactation [Figure 1] [21-22].

➤ Antimicrobial Property

Invitro studies say that spirulina has 15 volatile components (Tetradecane, Isophytol, Phytol etc.) which are responsible for the antibacterial effect. The extract of volatile components inhibits the microorganism growth. Spirulina platensis exhibits activity against both Gram positive and Gram-negative bacteria. The ethanol extract of spirulina platensis inhibits the infection of Enterococcus faecalis. The methanol extract of spirulina shows antibacterial activity against Streptococcus faecalis, Staphylococcus epidermidis Salmonella typhi and Pseudomonas aeruginosa [23-24]. The culture of cyanobacteria spirulina platensis inhibits the activity of various vibrio strains such as Vibrio splendidus, Vibrio lentus [25]. It reduces the activity of E. coli, Klebsiella Pneumonia, which has drug-resistant capability [26]. So, spirulina platensis is antibacterial as well as it works against drug- resistant bacteria.

A wide range of human illness is caused by 100 enteric virus species such as hepatitis, influenza etc. Recently pharmaceutical industry has worked on the new bioactive component which work as an antiviral agent. Spirulina is one of the natural products which have antiviral activity. It has the ability to work against the genetic material (RNA and DNA) of enteric viruses. Invitro Studies found that Braun-type lipoproteins from spirulina platensis ethanol extracts have effect on monocyte and macrophage cells and activate innate immunity and are involved in immunostimulation. It also has antiviral activity against foot and mouth disease virus strains (A, O, SAT2) [27].

The cold-water extract of spirulina platensis inhibits the replication of virus, blocks the viral plaque formation and decreases the viability and pathogenicity of several influenza. Spirulina platensis have substances like calcium spirulan (Ca-SP), that have the ability to inhibit some

enveloped virus such as the type 1 human immunodeficiency virus (HIV-1), influenza A virus, type 1 herpes simplex virus (HSV-1), mumps virus, measles virus replication and infection [28–31]. The aqueous extract of spirulina through immunomodulation prevents the replication of HIV- 1 in human T-cells, Langerhans cells and peripheral blood mononuclear cells [32]. The methanol extract of spirulina reduces the growth of adenovirus type 40 [33] and it also blocks the entry of Human simplex virus -1 in cells and reduce infection [28]. Spirulina platensis contains calcium spirulan which is also known as sulphated polysaccharide & is the major components that reduces the replication of HIV-1 and cytomegalovirus [29]. Spirulina is a natural antifungal compound which is cost-effective and more beneficial to health as compared to regular drugs. The ethanol extract of spirulina reduces the infection of Candida albicans which causes infections in oral and genital area in human [34]. The blue-green algae activate natural killer cells, T-cells, B-cells, macrophages, and many cytokines which are involved in immunostimulation and show antiviral, antifungal, antiparasitic, and antibacterial activity.

➤ Anti-Inflammatory, Antioxidant, Immunomodulator Properties

Atherosclerosis, heart failure, hypertension and many other diseases are caused by oxidative anxiety. The oxidative stress attacks and destroys molecules in the biological system. Thus, the extract of spirulina has multiple therapeutic effects including anti-inflammatory and antioxidant. Spirulina prevents oxidative stresses and reduces muscle injury. Spirulina also produces antibodies that induce anti-inflammatory and immunomodulator responses because these antibodies express the cytokine-coding genes. Spirulina has major phycobiliprotein known as chromophore phycocyanin that shows a broad effect such as neuroprotective, anti-inflammatory and anti-oxidative features [12, 24, 35-37]. The chromophore phycocyanin inhibits the exhibition of iNOS (inducible nitric oxide synthase) and COX-2 (Cyclooxygenase-2) which are inflammatory factors in lung tissue and macrophage and decrease inflammation activity [38-41]. It has a hepatoprotective effective. Phycocyanin exhibited activity against OH radical which is produced by ascorbate or iron or H₂O₂ (Hydrogen Peroxide) [42]. The increasing level of H₂O₂ significantly improves the function of antioxidant enzymes Catalase (CAT), peroxidase (PX), Superoxide dismutase (SOD), and ascorbate peroxidase (APx) in spirulina [43]. The aggregation of free radical's damages neurons in the brain and is responsible for neurodegenerative diseases, thus because of antioxidant activity of spirulina platensis it also used for the treatment of neurodegenerative diseases such as Alzheimer's or Parkinson's disease [43]. Spirulina has PC12 cells which protect against neurodegenerative diseases by inhibiting iron-induced free radicals [44]. Spirulina shows various benefits in human health, it works against hyperlipidemia, diabetes, ischemic disease, malignancy, heavy metal chemical-induced toxicity, anaemia, and radiation [45-48]. Phycocyanin and allophycocyanin also inhibit oxygen stress action against diabetic nephropathy [49]. Spirulina

influences antioxidant enzymes and suppresses damaging of DNA and lipid Peroxidation [50]. So, spirulina is an important agent used in the treatment of cardiovascular diseases and chronic obstructive pulmonary disease (COPD) [51-53]. Spirulina modulates cytokines such as tumour necrosis factor (TNF)- α and interleukin (IL-1 β , IL-2, IL-4, IL-6, IL-10) and show anti-inflammatory and immunomodulatory effects [54-57]. Cyclooxygenase-2 (COX-2) is an enzyme produced by prostaglandins which play a key role in inflammation [58]. Phycocyanin inhibits COX-2 and shows anti-inflammatory effects [59]. Phycocyanin and β -carotene which are involved in monitoring the ERK1/2(extracellular signal-regulated protein kinase 1/2), Arch Toxicol 1 3 JNK, I κ B, and p38 signaling pathways and show immunomodulator activity [60,61].

➤ *Antitumour & Anticancer properties*

Some studies also revealed that spirulina also contains anti-tumour and anti-cancer properties. Radachlorin is a new chlorine photosensitizer molecule present in spirulina and it has tumour regression properties [62]. The unique type of complex polysaccharides found in Spirulina reduces the growth of glioma cells by decreasing the production of interleukin-17 [63]. Spirulina platensis contain acidic polysaccharides which enhance the production of tumour necrosis factor- α (TNF- α) in macrophages [64]. Spirulina has a special type of polysaccharide that initiates the enzyme activity present in the cell nucleus and involved in the unification of DNA repair [65]. Chromophore phycocyanin represses cyclooxygenase-2 and promotes program cell death in lipopolysaccharide-stimulated RAW 264.7 macrophages, which shows anti-inflammatory as well as anticancer activity [66].

It also has tumour elimination property which plays a key role in cancer treatment. According to the research, adding supplements of Spirulina in the diet for a year completely overcomes leukoplakia [67-70].

➤ *Effect on Lower Cholesterol and Diabetes*

Mostly heart diseases like atherosclerosis are caused by high cholesterol levels in the body. Spirulina reduces low-density lipoprotein cholesterol and shows a significant effect on atherogenic and diabetes [71, 72].

➤ *Bioremediation and Anti Pollutant*

For the last few years, reports have found that industrial cities' rivers, lakes, and soil are very polluted, which is harmful to human health. Hundreds of agents, including crude oil, aliphatic, aromatic, phenol, pesticide, herbicide, insecticide, and various chemical substances contaminate the environment of Earth [73]. Spirulina is a potential candidate for eliminating pollutants from soil and water. Pesticide is applied for pest control in the agriculture field and enhances better crop production. The data show that about 90% of pesticides are used in Asian rice paddy fields, 80% in Bangladesh and Vietnam, and 47% in the Philippines [74] but in the ecosystem, pesticides are one of the chemical pollutants that accumulate in water and soil causing a serious environmental issue. Spirulina can absorb

the extra pesticide from crops and work as an antipesticide. Spirulina has large amounts of enzymes, peptides, etc., that help bind the toxic compound and then eliminate it. DDT(Dichlorodiphenyltrichloroethane) is an insecticide that has chemical stability so it stays in the environment for a long time. It enters humans through the digestive tract or skin which is harmful to nervous tissue [75]. Spirulina can adsorb and remove DDT, TNT(Trinitrotoluene)and Cs⁺ by cellular lipopolysaccharides from polluted water [76,77]. In the presence of the chelating compound, spirulina removes Cs⁺ ions from polluted water and works as an antipollutant. Spirulina is a key substance for the removal of toxic agents and also eliminates nitrogen from wastewater [78]. Glyphosate is used as an herbicide in the agriculture field but it harms the crops so spirulina is used as an anti-herbicide for removing glyphosate herbicide.

➤ *Miscellaneous Properties*

Cyanobacteria produced various compounds which provide protection against asthma, allergic rhinitis and many allergic responses [79]. Spirulina reduce the ischemic brain damage because it has also neuroprotective ability [80]. Spirulina produced a special type of compound, polyhydroxyalkanoates which play an important role in therapeutic. Evidence exhibit that polyhydroxyalkanoates, and 4- hydroxybutyrate are used for the treatment of alcohol withdrawal syndrome [81].

III. FUTURE PLAN

Spirulina is a natural product, that rapidly grow, has high photosynthetic activity, has high tolerance ability and various properties which open the way to producing useful products by synthetic biology. It is an excellent bioremediator which removes heavy metals, pesticides, and herbicides and cleans the environment. It has lots of potential so scientists can use genetic engineering tools and perform strain improvement to obtain high productivity. Researchers must explore the enhancement of cell potential for adaptation in extremely stressful conditions.

IV. CONCLUSION

This Literature provides a new approach of using spirulina in several applications such as nutritional agent, therapeutic drug, and environmental involvement. Spirulina is non-toxic and has many nutritional compounds and metabolites [Figure 2]. Various medicinal compounds found in spirulina are used as alternative medicine without any side effects. Its bioactive product is beneficial for human health. Based on the possibility of cyanobacteria, it can be used by industrialists for various product development. It provides an aim for researchers and scientists to investigate different cyanobacterial studies.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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FIGURE CAPTIONS

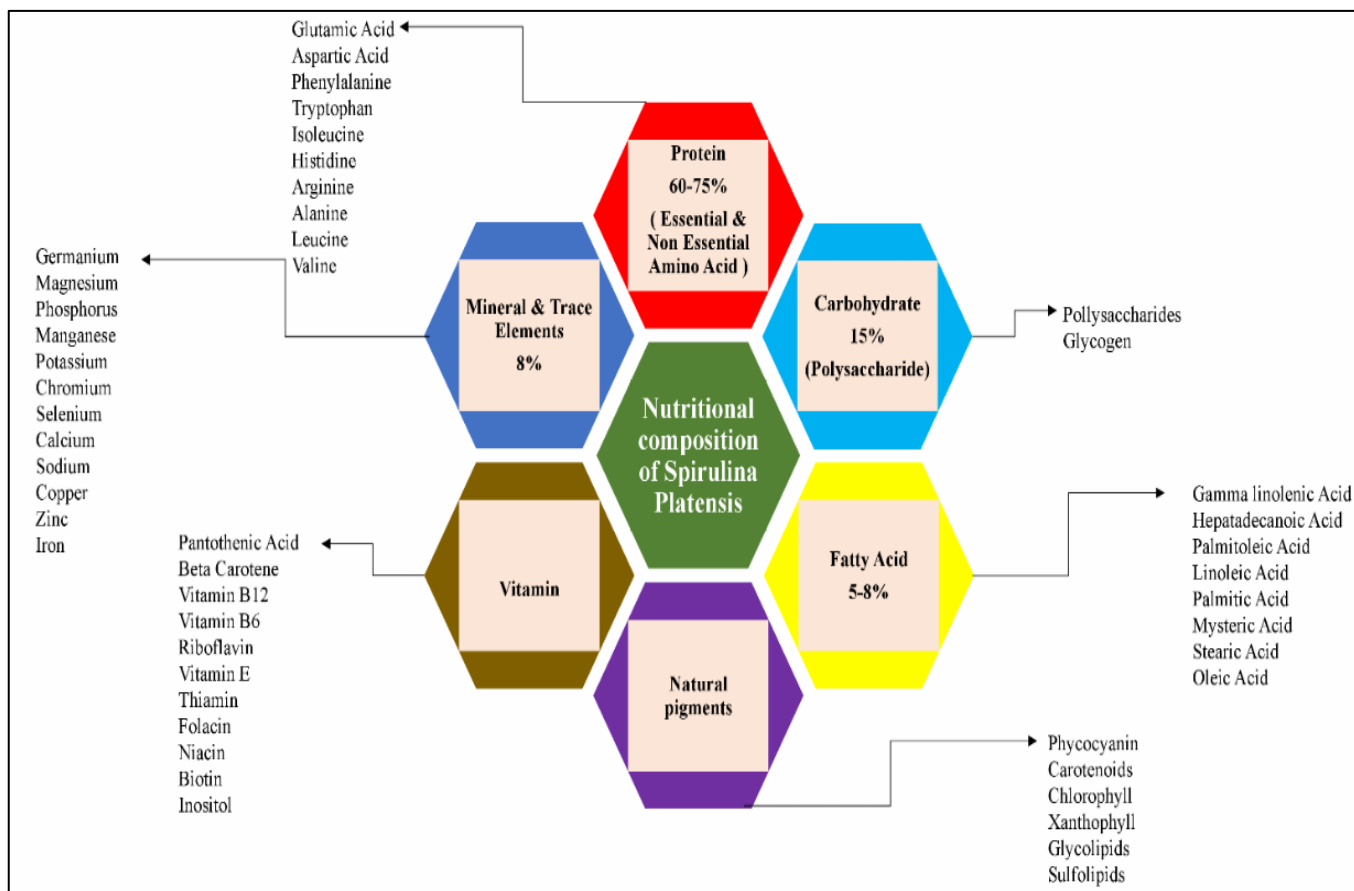


Fig 1. Nutritional Component of Spirulina

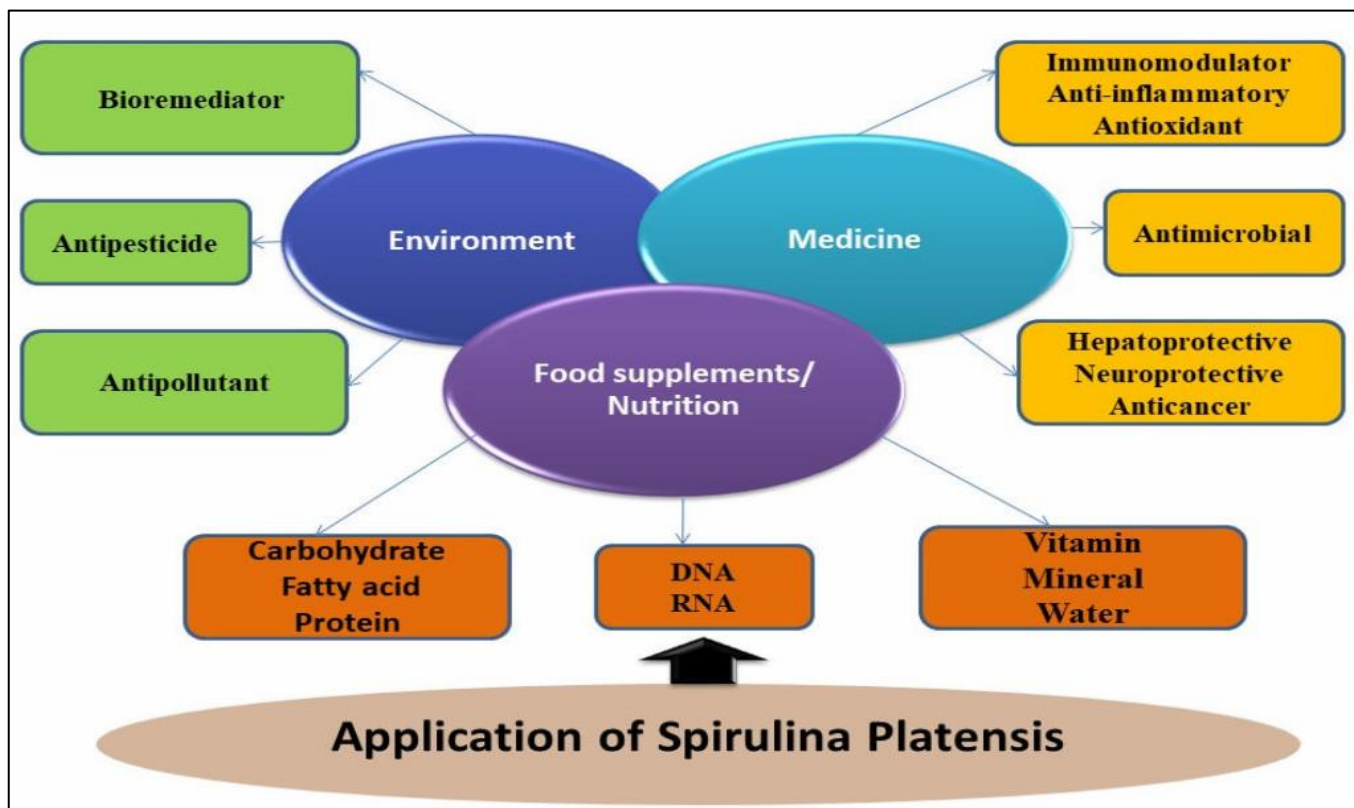


Fig 2: Application of Spirulina Platensis

Table 1. Biological Properties of Spirulina Platensis

S. No.	Properties	Cellular Component	Application	References
1.	Nutritional Properties	Protein, Vitamin B6, Provitamin A and Vitamin B12, Lipid, Carbohydrates, Water, RNA, DNA, Calcium content, Iron	Bone weaking, Anaemia	15-22
2.	Antibacterial Properties	Ethanol Extract	Urinary Infection	23-24
		Methanol Extract	Typhoid Fever	
3.	Antiviral properties	Extract	Foot and Mouth Disease	27
		Cold water Extract	Influenza	28-31
		Calcium Spirulan	HIV-1, Influenza, Herpes, Mumps, Measles	
		Aqueous Extract	HIV- 1	32
		Methanol Extract	Adenovirus infection, Human simplex virus infection	33,28
4.	Antifungal Properties	Ethanol Extract	Oral and Genital infection	34
5.	Immunomodulator properties	Chromophore Phycocyanin	Neuroprotective, Anti-inflammatory, Anti-oxidative Features	12, 24, 35-37
		PC12 cells	Neurodegenerative Diseases	44
		Phycocyanin and Allophycocyanin	Diabetic Nephropathy	49
		Phycocyanin and β -carotene	Immunomodulator Activity	60,61
6.	Anticancer properties	Radachlorin	Tumour regression Property	62
		Polysaccharide	Decreases the growth of glioma cell and DNA repair	63,65
		Acidic Polysaccharide	Enhance the production of TNF- α	64
		Chromophore Phycocyanin	Anticancer	66
7.	Bioremediation properties	Cellular Lipopolysaccharides	Remove DDT, TNT	76,77
8.	Miscellaneous properties	Polyhydroxyalkanoates and 4-Hydroxybutyrate	Alcohol withdrawal syndrome	81